The Preference Analysis for Optimum Density and Understory Vegetation Management in Healing Forests

Jeong Seok Kang, Jeong Deok Ju, and Chang Seob Shin*

Department of Forest Science, Chungbuk National University, Cheongju 28644, Korea

ABSTRACT

The purpose of this study is to suggest how to manage healing forests. Field investigation and surveys were conducted to produce results and 313 questionnaires collected from workers in the forestry sector and ordinary people were analyzed. The results were as follows: it is required to preserve flowering plants, scenic trees, and ecological trees in the understory vegetation, and to remove trees that block the forest landscape, leaving about 50 to 60 percent of the understory vegetation. The preferred density order of broadleaf trees was analyzed as follows: *Betula platyphylla* > *Liriodendron tulipifera* > *Quercus acutissima*. The preferred density order of coniferous trees was analyzed as follows: *Abies holophylla* > *Cryptomerias japonica* and *Chameacyparis obtusa* > *Larix kaempferi* > *Pinus densiflora* > *Pinus koraiensis*. The preferred density in healing forests was 81–89% compared to the number of residual trees for quantitative thinning. Specifically, the preferred density were 87% for *P. koraiensis*, 86% for *L. kaempferi*, 81% for *P. densiflora*, 83% for *C. japonica*, 84% for *C. obtusa* and 89% for *Q. acutissima*. In the case of healing forests, it is recommended to periodically conduct a small-scale thinning with different densities according to the species and diameter of trees based on the results of this study.

Keywords: flower trees, forest landscape, preferred density, quantitative thinning, scenic trees

Introduction

As the times have changed, the landscape of forests has been significantly transformed, so have people's perception of forests. The roles of forests in the past were mainly to produce fuel and lumber and to conserve the national land, but today we are living in an era where the public value of forests is 20 times higher than their net production value. As people's quality of life improves, and the public value of forests increases, the Korea Forest Service issued a guidelines for classifying and differentiating forests by function.

For the past 50 years, Korea has experienced rapid economic development and already entered an aged society, and in 2025 it is expected to become a super-aged society where over 20% of the total population is aged 65 and older. Industrialization, the foundation of economic devel-

opment, has expanded urban areas and at the same time has reduced the area of forests, and people in modern society have been exposed to various environmental sources of stress, which has threatened their health (Park and Miyazaki, 2008). In particular, as the share of the aged whose immunity weakens increases, people's interest in health has continuously increased.

As aging has been accelerated, the number of people who want to visit forests has increased, and the number of recreational or healing forests has also increases annually. As of now, nine healing forests are publicly operated under the Korea Forest Welfare Institute, and seven healing forests are under creation (Korea Forest Welfare Institute, 2019). These healing forests are evenly distributed across the country. In addition, as people's interest and demand for healing forests increase, local governments and private

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First author: Jeong Seok Kang, Kangjs0811@hanmail.net, <https://orcid.org/0000-0002-6017-282X>

***Corresponding author:** Chang Seob Shin, sinna@chungbuk.ac.kr, <https://orcid.org/0000-0002-6298-1487>

organizations started to operate healing forests.

Currently, forests in Korea are classified into six functions, and are managed under guidelines by function. However, no official guideline has been issued yet for managing healing forests of which number has increased annually.

It is important to reflect the opinions of program operators in managing healing forests, and thus to qualitatively thin trees (Kim et al., 2015), but it is also very important to consider the density of standing trees. Lee (2011) surveyed the preferred density (three grades) of trees including *Pinus densiflora*, *Pinus koraiensis*, *Hinoki cypress* and *Larix Kaempferi*, and Shin et al. (2013) reported that people preferred 60-80% of the density of pine forests for forest healing compared to trees for producing lumber. Arthur (1977) reported that people's visual preference in large-pole, mature stands of trees was higher than in young forests, and another study suggested that the optimum density of standing trees (DBH 20-30cm) to secure comfortability in forests is 700-800 trees/ha. Since the density of standing trees is an important element that affects people's perception of forest landscapes (Brown and Daniel, 1986; Brush et al., 1979; Hull and Buhyoff, 1986), it needs to be considered as an essential element in creating and managing pleasant healing forests. As such, several studies have been conducted on the management of recreational and healing forests, but most of them were fragmentary. For this reason, it is necessary to conduct more systematic studies on various species of trees.

Against this backdrop, this study aimed to review methods for managing the understory vegetation along the trails of healing forests, to determine the optimum density of various species of trees by diameter, and thus to suggest ways to manage healing forests.

Research Methods

Unlike earlier studies, this study investigated the density of standing trees in an area where the key species of trees of different diameters that grow in Korea are distributed, and selected one of the areas targeted by the forest-tending project to survey the understory vegetation through on-site and questionnaire surveys.

On-site survey

Management of understory vegetation

One of the areas where the forest-tending project was initiated is the area of standing *Larix kaempferi* and broad-leaved trees located in San 79-3, Majang-ri, Gwangtan-myeon, Paju-si in 2016. People's preference for methods for managing the understory vegetation in the area was surveyed with photos taken the next year, and the area was divided into the following groups: ① forest with no understory vegetation removed (control group), ② forest with bad sub-trees and a part of the understory vegetation removed (about 40% removed), ③ forest with no flowering trees removed, but sub-trees and bad understory vegetation removed (about 50% removed), ④ forest with most of the understory vegetation removed (about 80% removed), and ⑤ forest with all the understory vegetation removed (100% removed).

Density of standing trees

To examine the density of standing trees, six major coniferous tree species that grow in Korea (*Pinus densiflora*, *Larix kaempferi*, Korean Pine, *Abies holophylla*, *Hinoki cypress* and *Japanese cedar*) and three broadleaf tree species (oak trees, *Betula platyphylla* and *Liriodendron tulipifera*), a total of nine species of trees were classified by diameter as follows: small-diameter (B11-20cm), medium-diameter (B21-30cm), large-diameter (B31-40cm) and super-large-diameter (B41-50cm). One standard land was selected for each species and diameter class, and a total of 29 standard lands were surveyed in the following areas: Gangneung and Inje in Gangwon-do; Gapyeong, Yangju and Paju in Gyeonggi-do; Namdong-gu in Incheon; Mungyeong in Gyeongbuk; and Jangseong in Jeonnam. The size of standard lands was 400m² (20m×20m), and all the standing trees within the standard lands were surveyed to calculate their average diameter. Elevation drawings used in questionnaire surveys were produced in 3D after recording the diameter of the standing trees at breast height and their location on a graph paper of the standard survey form.

Questionnaire survey

Subjects and analysis

To ensure at least 0.1% of the total workers in the areas associated with forestry in Korea (as of 2017, 253,000 workers) were surveyed, 330 persons were targeted, and a questionnaire survey was conducted through online surveys and door-to-door interviews. The data of 204 workers in the forestry sector and 109 ordinary people (200 males, 100 females, 13 not responded) were collected. The surveyed workers in the forestry sector included forest experts (professional engineer forestry), forestry project design and supervision (engineering), forestry construction (forestry associations and corporations), public officials in green lands, academia, researchers, forestry-related organizations, forest therapists, forest expounders, and students in forestry departments. The surveyed ordinary people were included to analyze differences in opinion between them and workers in the forestry sector.

Descriptive statistical analysis and frequency analysis were conducted on the collected data using MS Excel and SPSS programs.

Calculation of the number of trees for tree density

To survey their preferred density of standing trees, the number of standing trees surveyed on site was set as 100, and the thinning rate was reduced by about 20%. Images of the standard lands and six items for each diameter class were produced in 3D for the questionnaire survey. Based on the surveyed data, the preferred number of standing trees was determined using the Equation 1. In order to ob-

tain data as accurate as possible, the number of respondents who selected Preference Ranks 1-3 among six items was multiplied by the number of trees. The preferred number of trees for six items was calculated, and the average of the sum of trees preferred by subjects who ranked first, second and third was applied to the density per ha.

The reason why the thinning rate was reduced by 10-20% compared to the number of trees to produce graphics was that the interval of 10~20% is the standard thinning intensity for light thinning.

$$\text{Calculated number of standing trees for tree density} = \frac{(N1 \times A1) + (N2 \times A2) + (N3 \times A3)}{\sum AN} \quad (1)$$

where N1: number of trees preferred by subjects who ranked first in preference/ha.

A1: number of subjects who ranked first in preference.

N2: number of trees preferred by subjects who ranked second in preference/ha.

A2: number of subjects who ranked second in preference.

N3: number of trees preferred by subjects who ranked third in preference/ha.

A3: number of subjects who ranked third in preference

$\sum AN$: total number of subjects who ranked first, second and third

Results and Discussion

Analysis of preferred spatial closure rate of understory vegetation

To analyze the preferred methods for managing the understory vegetation, forests were divided into five groups, and their photos were used in the questionnaire survey, and the results were as shown in Table 1. The preferred methods were surveyed as follows: Forest with flowering

Table 1. Preference for undrestory vegetation density in healing forests by forestry worker and the public

Division	Forestry worker		Ordinary people		Total	
	Frequency	Percent (%)	Frequency	Percent (%)	Frequency	Percent (%)
Forest with no understory vegetation removed	3	1.5	5	4.6	8	2.6
Forest with 40% of the understory vegetation removed	74	36.3	41	37.6	115	36.8
Forest with flowering trees preserved, but 50% understory vegetation removed	88	43.1	42	38.5	130	41.5
Forest with 80% of the understory vegetation removed	27	13.2	11	10.1	38	12.1
Forests with all the understory vegetation removed	9	4.4	6	5.5	15	4.8
No response	3	1.5	4	3.7	7	2.2
Total	204	100	109	100	313	100

trees preserved, but 50% understory vegetation removed (41.5%) > forest with 40% of the understory vegetation removed (36.8%) > forest with 80% of the understory vegetation removed (12.1%) > forest with all the understory vegetation removed (4.8%) > forest with no understory vegetation removed (2.6%). There was no difference in opinion between workers in the forestry sector and ordinary people. Overall, over 78% of respondents were found to prefer forests with bad sub-trees and 40-50% of the understory vegetation removed without removing flowering and landscape trees.

The understory vegetation in forests is significantly affected by the crown density of upper trees. In other words, since the shrub layer is highly related with upper trees, the species diversity of forests decreases over time, and the herbaceous layer is affected by the shrub layer (Cheon et al., 2014).

Based on the surveyed and analyzed results above, methods for managing the understory vegetation in healing forests can be suggested as follows. Since the density of standing trees significantly affects the understory vegetation, it is necessary to remove bad sub-trees and determine whether to leave flowering trees in the understory vegetation such as *Rhododendron mucronulatum* based on their conditions while controlling the density of the upper layer in healing

forests. Meanwhile, when thinning or tendering forests, the understory vegetation is often damaged. For this reason, when removing damaged trees, fallen or broken trees, trees that block the landscape and bad trees, about 50-60% of the understory vegetation naturally remains. When it is difficult to maintain the level, it is necessary to artificially remove some part of the underlying layer to leave 50-60% only.

Table 2 and Fig. 1 show the case where flowering trees such as *Rhododendron mucronulatum*, *Symplocos paniculata* and *Stephanandra incisa* were not removed as

Fig. 1. Comparison of crown closure before (left) and after (right) forestry management. S-o = *Styrax obassia*; C-c = *Castanea crenata* var. *dulcis*; A-p = *Acer pseudosieboldianum*; C-h = *Corylus heterophylla*; S-c = *Symplocos chinensis* for. *pilosa*; R-m = *Rhododendron mucronulatum*; S-i = *Stephanandra incisa*; P-s = *Prunus sargentii*; S-j = *Styrax japonica*; V-e = *Viburnum erosum*; Q-m = *Quercus mongolica*; P-k = *Pinus koraiensis*; L-o = *Lindera obtusiloba*.

Table 2. Case studies of forest understory management

Species	Number of pre-treatment trees	Treatment		
		Cutting	Pruning	Remaining
<i>Styrax obassia</i>	4	2	2	2
<i>Castanea crenata</i> var. <i>dulcis</i>	6	6		0
<i>Acer pseudosieboldianum</i>	4	1	2	3
<i>Corylus heterophylla</i>	6	2		4
<i>Symplocos chinensis</i> for. <i>pilosa</i>	5	2		3
<i>Rhododendron mucronulatum</i>	4	0		4
<i>Stephanandra incisa</i>	2	0		2
<i>Prunus sargentii</i>	1	0	1	1
<i>Styrax japonica</i>	2	1	1	1
<i>Viburnum erosum</i>	2	1		1
<i>Quercus mongolica</i>	4	2		2
<i>Pinus koraiensis</i>	1	0		1
<i>Lindera obtusiloba</i>	1	0		1
Sum	42	17	6	25

much as possible, and 60% of the total number of standing trees were left.

Analysis of preference depending on density of standing trees and crown density

Density of standing trees by species and diameter class

The density of standing trees in 29 standard lands for nine different species was surveyed. When the thinning rate was reduced by 10-20%, the number of standing trees was as shown in Table 3. Based on the results, a total of 174

3D images for different species, diameter classes and residual rates were produced to survey subjects' preference for the density of standing trees (Fig. 2).

Analysis of preference for density of standing trees by species and diameter class

A questionnaire survey was conducted with graphic images for individual standard lands and six items, and the number of respondents who ranked 1st-3rd in preference was multiplied by the number of trees to calculate their preferred number of standing trees as shown in Table 4.

Table 3. Number of standing trees by diameter class

Species	Diameter class	Number of trees in plot	Number of trees after application of residual rate				
			70-80%	55-60%	45-50%	33-40%	20-30%
<i>Pinus koraiensis</i>	18	1,100	875	670	550	400	325
	28	700	525	400	325	250	160
	38	525	400	300	250	175	150
	48	350	250	200	175	125	100
<i>Larix kaempferi</i>	16	1,600	1,200	900	725	550	375
	22	1,000	775	600	475	375	250
	32	600	450	350	275	200	150
<i>Pinus densiflora</i>	18	1,550	1,225	950	760	575	400
	26	1,000	800	600	500	350	250
	38	525	450	375	300	225	175
	46	400	275	200	175	120	100
<i>Cryptomeria japonica</i>	16	2,000	1,525	1,275	1,025	775	600
	24	1,250	1,050	825	675	550	425
	34	800	650	500	400	325	275
<i>Chamaecyparis obtusa</i>	12	2,400	2,000	1,700	1,350	1,025	775
	20	1,700	1,400	1,075	875	675	500
	30	950	775	600	500	400	275
<i>Abies holophylla</i>	16	1,525	1,300	1,075	850	650	525
	28	775	675	550	450	325	275
	34	725	625	525	400	300	225
	46	625	550	450	350	250	225
<i>Quercus acutissima</i>	14	1,300	850	750	600	450	300
	22	875	650	500	400	300	275
	32	600	450	350	275	225	150
<i>Liriodendron tulipifera</i>	12	1,600	1,375	1,125	900	650	575
	22	1,200	1,025	850	675	500	425
	32	700	600	500	400	300	250
<i>Betula. platyphylla</i> var. <i>japonica</i>	12	1,850	1,575	1,300	1,000	750	650
	22	1,200	1,025	850	675	500	425

Fig. 2. Created 3D images of larch trees (DBH 22cm) forest with different density for preference survey.

Table 4. Analysis of density preference by tree species and diameter class

Species	Diameter class	Preferred tree number by respondent (number/ha)			
		Forestry worker	Ordinary people	Mean	Applicable number
<i>Pinus koraiensis</i>	18	575	580	577.5	580
	28	343	348	345.5	350
	38	242	222	232	230
	48	179	178	178.5	180
<i>Larix kaempferi</i>	16	759	765	762	760
	22	512	521	516.5	520
	32	310	310	310	310
<i>Pinus densiflora</i>	18	769	780	774.5	780
	26	490	487	488.5	490
	38	315	367	341	340
	46	215	212	213.5	210
<i>Cryptomeria japonica</i>	16	1,038	1,034	1,036	1,040
	24	695	710	702.5	700
	34	504	516	510	510
<i>Chamaecyparis obtusa</i>	12	1,368	1,389	1,378.5	1,380
	20	915	930	922.5	920
	30	601	607	604	600
<i>Abies holophylla</i>	16	1,102	1,113	1,107.5	1,110
	28	556	566	561	560
	34	452	453	452.5	450
	46	327	332	329.5	330
<i>Quercus acutissima</i>	14	650	653	651.5	650
	22	435	441	438	440
	32	280	281	280.5	280
<i>Liriodendron tulipifera</i>	12	847	879	863	860
	22	612	608	610	610
	32	397	409	403	400
<i>Betula. platyphylla</i> var. <i>japonica</i>	12	1,029	1,029	1,029	1,030
	22	811	806	808.5	810

In the case of *Pinus koraiensis* of 18cm in diameter at breast height, workers in the forestry industry and ordinary people were found to prefer 575 and 580 trees per ha respectively, and thus 580 trees were applied. As shown in Table 4, there was no significant difference in opinion between them, and the applied number of trees was determined by rounding it off to the nearest integer.

As shown in Table 4, in the case of broadleaf trees such as *Quercus acutissima*, *Liriodendron tulipifera* and *Betula platyphylla*, respondents were found to prefer them within the same diameter group in the following order: *Betula platyphylla* > *Liriodendron tulipifera* > *Quercus acutissima*. The results can be attributed to the fact that *Betula platyphylla* that has white bark tends to look more beautiful when its density is high. In addition, the branch angle of *Liriodendron tulipifera* is smaller than that of *Quercus acutissima*, and thus its crown width is smaller and its trunk is straight. For this reason, respondents seemed to prefer the higher density for *Liriodendron tulipifera* compared to *Quercus acutissima*. In the case of *Larix kaempferi*, *Cryptomeria japonica* and *Cryptomeria japonica* among coniferous trees, respondents were found to prefer them within the same diameter group in the following order: *Cryptomeria japonica* > *Cryptomeria japonica* > *Larix kaempferi*. In the case of *Chamaecyparis obtusa* that has a similar shape, it was difficult to directly compare it with others as there was no species that has a similar diameter, but it was found that respondents preferred *Chamaecyparis obtusa* with the similar density to *Cryptomeria japonica*. Meanwhile, in the case of *Pinus densiflora* and *Pinus koraiensis* that have a wider crown width than the four coniferous trees above, respondents preferred a lower density, and the preferred density of *Pinus koraiensis* was smaller than that of *Pinus densiflora*.

Conclusion

The results of the questionnaire survey on the management of the understory vegetation in healing forests showed that over 78% of respondents preferred forests with bad sub-trees and 40-50% of the understory vegetation removed without removing flowering and landscape trees. This was

commonly observed between workers who directly managed forests or were involved in the forestry sector and ordinary people. Based on these results, it is recommended to leave flowering and landscape trees as much as possible and remove 40~50% of the understory vegetation when tending healing forests. As a method for managing the understory vegetation, this study suggests to leave flowering and landscape trees and ecological trees in the understory vegetation, and to remove or thin trees that damage forests, damaged, fallen or broken trees, trees that block the landscape and bad trees, leaving about 50-60% of the understory vegetation.

In addition, the optimum density of standing trees of nine species was surveyed, and in the case of broadleaf trees, respondents were found to prefer them within the same diameter group in the following order: *Betula platyphylla* > *Liriodendron tulipifera* > *Quercus acutissima*. In the case of coniferous trees, *Larix kaempferi*, *Cryptomeria japonica* and *Cryptomeria japonica* that have a similar shape were surveyed, and respondents were found to prefer them within the same diameter group in the following order: *Cryptomeria japonica* > *Cryptomeria japonica* > *Larix kaempferi*. In the case of *Pinus densiflora* and *Pinus koraiensis* that have a wider crown width, respondents preferred a lower density than other needleleaf trees, and the preferred density of *Pinus koraiensis* was smaller than that of *Pinus densiflora*.

The optimum density for standing trees differed depending on the diameter and species of trees, and the wider the crown width of trees, the lower density people tended to prefer. Therefore, when tending healing forests, it seems to be effective to vary their density depending on their species and diameter class and to perform light thinning of 10-20% regularly.

The optimum density of the nine species surveyed in this study was listed in Table 4. Since healing forests are composed of various tree species, it will be necessary to conduct more studies on the direction for creating the understory vegetation in healing forests and the optimum density of various tree species.

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